GEOLOGIC MAPPING OF SEDIMENTARY MATERIALS IN THE NORTHERN PLAINS OF MARS; **Kenneth L. Tanaka,** U.S. Geological Survey, Flagstaff, AZ 86001; ktanaka@flagmail.wr.usgs.gov

Introduction. Geologic studies have gradually revealed that most of Mars' northern plains are likely made up of sedimentary or mass-wasted materials rather than volcanic rocks, which cover the plains only in the Tharsis and Elysium regions [e.g., 1-2]. These studies have proposed that (a) patches of closely spaced knobs along the highland/lowland boundary and in the plains are mass-wasted cratered terrain material [1-3], (b) polygonally fractured plains materials in Acidalia and Utopia Planitiae may be thick sedimentary deposits [4-5], (c) coarse, channeled plains deposits in Utopia Planitia may be lahars or jökulaups from the flanks of Elysium Mons [6-7], (d) lacustrine sediments were deposited in a plains-filling ocean [8], and (e) debris flows cover much of the northern plains from highland outflow channels or melted polar layered deposits [9-10].

Until recently, mapping of the northern plains has mainly recorded geomorphic units that document the distribution of various features, including knobs, grooves, ridges, and mottling (see the Vastitas Borealis Formation in [1-3]). In some cases, relative ages among some units were determined by crater counts, such as for members of the Arcadia Formation [1]; however, many large outcrops of plains units have not been crater counted. Recent identification of a series of mappable sedimentary deposits in Chryse and Acidalia Planitiae [10] has provided a much improved basis for the mapping and crater counting of actual stratigraphic units throughout the northern plains and for understanding the origin of various geomorphic features.

Mapping sedimentary units. Caution must be exercised in mapping northern plains units. Although many types of geomorphic and albedo features may assist in identifying rock units, such features commonly are not characteristic of the entire unit or of one unit alone. The most definitive and helpful characteristics for mapping purposes appear to be those that demarcate or form along unit boundaries. Easiest to map along edges of deposits are lobate scarp fronts of possible mass-flow origin [10-11] (e.g., Chryse unit 4 and Utopia unit 1). The scarp fronts commonly wrap around small knobs that may have impeded flow. Also, the fronts are commonly associated with unusual troughs having medial ridges (a notable example occurs northeast of Kipini crater at 27° N., 29° W.). The troughs and ridges have been interpreted as subglacial or coastal depositional and erosional features [11-12], but their invariable formation within and along the edges of flow deposits indicates that they originated by some sort of a fluid or plastic deformation. For the Isidis unit, trough and ridge features near the deposit edge are generally easier to discern than the edge itself. In some cases, features such as knobs, fractures, pits, wrinkle ridges, thumbprint terrain, hummocky terrain, and contrasting albedo assist to characterize units, and they can be useful for inferring unit correlations among isolated outcrops. For example, pitted plains material in Chryse Planitia and Ares Vallis have similar stratigraphic positions and appear to have been separated by the latest episode of Simud/Tiu Valles dissection; both outcrops are mapped as Chryse unit 2 [10].

Results. Using the above stratigraphic indicators, I have begun remapping the northern plains at 1:15,000,000 scale, identifying units typically forming outcrops hundreds to thousands of kilometers in extent (Table 1). In some areas, contacts appear sporadically or not at all due to inadequate image resolution and (or) quality, eolian mantling, or geomorphic (periglacial?) modification. In particular, the undivided plains unit may be composed of several major plains units whose contacts cannot be traced north of 60° N. In turn, some of the plains units appear to be made up of multiple deposits, such as Elysium unit 2, which comprises a series of flow and channel deposits from multiple sources on the flanks of Elysium Mons. Other plains units, such as the Chryse and Isidis units, appear to have local highland sources that can be traced directly or inferred [e.g., 10].

The approximate stratigraphic sequence is as follows (see also Table 1). Cratered terrain mass-wasted during the Noachian and Early Hesperian, forming the knobby unit. Early Hesperian plains material, deformed by wrinkle ridges, has been preserved mainly in higher elevation areas along the highland boundary and in Arcadia Planitia. Widespread plains sedimentation ensued during the Late Hesperian and Amazonian from erosion of local highland sources, including volcanic, tectonic, and ancient cratered terrains. Polar layered deposits and dunes form the youngest deposits. Refinements to this stratigraphy will result from further mapping and crater counting.

GEOLOGIC MAPPING: MARS; Kenneth L. Tanaka

Table 1. Preliminary compilation of probable sedimentary and mass-wasting units in the northern plains of Mars showing location (approximate center in some cases), extent, geomorphic characteristics, and stratigraphic relations; units shown in approximate stratigraphic sequence (youngest at top).

Unit name	Location	Extent (km)	Geomorphic characteristics and stratigraphic relations
Polar dunes	72-85° N.		Patches 100's of km across; linear and barchan dune patterns; overlies undivided plains unit
Polar layered	>~80° N.	1,200x1,100	Thick plateau of layered material, swirled pattern of troughs; overlies undivided deposits plains unit
Cerberus unit	0° N., 200° W	3,000x500	Smooth, thin; lobate flows at terminus in Amazonis Planitia; overlies lava flows in Elysium and Amazonis Planitiae and high plains unit, Upper Amazonian crater density
Isidis unit	13° N., 271° W.	800x800	Chains of pitted domes, marginal troughs and ridges; overlies high plains unit
Arcadia unit	47° N., 184° W.	800x200	Intersecting troughs (southern part) and thumbprint ter rain (northern part); overlies high plains unit
Undivided unit	>~60° N.	3,500x3,500	Hummocky plains of Vastitas Borealis, local polygonal fractures, mottled; grades into other plains units where contacts detectable
Elysium unit 2	42° N., 240° W.	1,900x800	Hummocky, channeled, lobate edges; overlies Elysium unit 1 and Utopia units 1 and 2
Elysium unit 1	31° N., 240° W.	1,300x200	Smooth; overlies Utopia unit 1
Utopia unit 2b	48° N., 220° W.	2,000x>700	Hummocky, polygonal grooves; may overlie Utopia unit 2a
Utopia unit 2a	50° N., 269° W.	1,000x>800	Hummocky, patches of thumbprint terrain, polygonal grooves; overlies Utopia unit 1
Utopia unit 1	30° N., 255° W.	3,000x800	Lobate scarp, smooth margin with troughs and ridges, hummocky interior with local thumbprint terrain; overlies high plains unit
Chryse unit 4	40° N., 30° W.	>3,000x>1,800	Scarp edge, fractures, troughs, ridges, pitted domes; buries Chryse units 1-3
Chryse unit 3	18° N., 37° W.	1,500x800	Scarp edge, small knobs, local scablands; embays Chryse unit 2; buries Ares Vallis
Chryse unit 2	32° N., 44° W.	2,200x400	Smooth plains, local pits; buries Ares Vallis
Chryse unit 1	30° N., 23° W.	1,500x500	Knobs, smooth plains; eroded by Ares Vallis, includes some knobby unit
Deuteronilus unit	47° N., 350° W.	>1,000x?	Scarp edge, fractures, pitted domes, troughs, ridges; Lower Hesperian crater density High plains unit Local patches of smooth plains along highland boundary and in Arcadia Planitia; wrinkle ridges common, local knobs; generally embayed by other plains units, Lower Hesperian crater density in places, embays knobby unit Knobby unit Patches of closely spaced knobs along highland boundary and in plains, some large crater rims; embayed by surrounding plains units

References. [1] Scott and Tanaka, 1986, *USGS Map I-1802-A.* [2] Greeley and Guest, 1987, *USGS Map I-1802-B.* [3] Tanaka and Scott, 1987, *USGS Map I-1802-C.* [4] Lucchitta et al., 1986, *PLPSC 17*, *JGR 91*, E166-E174. [5] McGill, 1986, *GRL 13*, 705-708. [6] Christiansen, 1989, *Geology 17*, 203-206. [7] Chapman, 1994, *Icarus 109*, 393-406. [8] Parker et al., 1989, *Icarus 82*, 111-145. [9] Jöns, 1991, *The Planet Mars (map),* Lithographisches Inst., Berlin. [10] Tanaka, in press, *JGR.* [11] Parker et al., 1993, *JGR 98*, 11,061-11,078. [12] Kargel et al., 1995, *JGR 100*, 5351-5468.